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1. INTRODUCTION

The Military faces unique challenges training medical personnel for deployment to combat zones. Pre-deployment, military personnel may not be routinely performing the emergent procedures that they will be expected to perform in theater. The training must be completed during a short period of time and in a “hyper-realistic” stressful and shocking environment. An understanding of how the training modality impacts the translation of the skills learned in training to actual practice, the degree to which those skills may decay over time and the impact of a stressful environment on acquisition and retention of clinical skills is critically important. The Combat Casualty Training Initiative instituted by the Telemedicine & Advanced Technology Research Center (TATRC) is attempting to address several of the complicated aspects of training military health care providers. This project developed a preliminary “proof of concept” to measure the impact, return-on-investment, and translation of the Department of Defense’s medical education training objectives. The integration of simulation technology has augmented but not replaced the live animal model for many emergency procedures in the complex educational training system of the military to prepare medical personnel for deployment to combat zones. This project describes: 1) a formative evaluation to inform the project; 2) a proof of concept test using system dynamics (SD) that can assist in determining if simulation can replace the use of live animals in DoD medical readiness training if populated with data; and 3) an assessment of whether the environmental stressors and distractions (both auditory and visual) in the simulated training environment adequately prepare the medical personnel for the stress of the combat theater if populated.

The reverence for data as the source of knowledge seems to be the rule for evidence. In this respect, system dynamics has much to offer. One of its trademarks is “operational thinking”, a distinct attitude that, unlike scientific practices that seek to understand the world by means of data analysis, seeks to transform systems in terms of operations. Operational thinking means to recognize agency as the driving force through which systems actually work: free decision makers invent their own future through actions that shape and create systems; they do not obey laws to be discovered by observing the past. As a standard example, if we observe several college aged women, we cannot use their past behavior to make a good estimate of future behavior when it comes to marriage and children. As a rule, education staves off age of marriage and age of first birth. However, the conundrum is that most of these college aged women will go on to have families with both spouses and children. Thus, the past cannot predict the future but looking at the behaviors of other women who went to college does inform the system and helps to explain and estimate future behaviors. System dynamics models provide intelligible explanations that meet such agency. Redesigning and improving human systems require then the capacity to realize and transform operational arrangements, that is, to understand and change decision processes and purposeful actions. System dynamics modeling relies on both quantitative and qualitative data and allows us to run simulations on policies and protocols. It derives information to make estimates not from study subjects past behavior but from experts with similar experiences. The “building blocks” of SD, “operational thinking” rarely makes is included in SD modeling. SD modelers usually build operational models but this special characteristic is hardly spelled out to make the most of it. Our purpose in using SD modeling to determine whether the DoD can safely reduce live tissue use and replace it with simulators, was to uncover the significance of operational thinking for modeling social systems. Thinking in terms of operations represents a distinct paradigmatic posture, different from the widespread, scientific paradigm that seeks to understand human systems through data analysis. This latter path conveys opportunities but also risks. This study shows why operational thinking is indeed a distinct way of “thinking”, a way of seeing. Instead of developing knowledge by observation of live tissue training, we formulate more general statements, the production of knowledge through operational modeling does not rest on data in order to bring understanding. (see example of college age women having families above). Rather, it relies on the generation of dynamic hypotheses such as H_1 : The DoD

can safely reduce the use of animals in medical training. We can explain the performance of a system based on its structure that is formed by operations. In turn, thinking in terms of operations in social systems means to think in terms of actual decision making processes continuously carried out by free actors. From this perspective, the performance of a social system is recognized as the result of human action.

The recognition of operational thinking as a distinct, separable and intrinsic element of SD represents various opportunities. The prominence of understanding over data analysis is a key example. It is not uncommon to hear that "rigor" means adequate data analysis of "empirical evidence" for justifying model building and valid results. SD models are certainly empirical since they are built from sense experience (rather than from pure theory or logic) and are checked against experiential information; but this is not equivalent to stating that SD models are built inductively from observed data. The current resurgence of data-driven research just boosts pressure.

Finally, this project generated 4) a preliminary return on investment (ROI). An ROI is the benefit to an investor resulting from an investment. In our case, that investment is the purchase and care of maintaining animals or the costs of purchasing sophisticated simulators and replacing the tissue of the simulator after use. An ROI that is large means the investment gains compare favorably to investment cost. As a performance measure, ROI is used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments (animals, animal food, animal housing, caretakers, simulators, replacement parts, etc). In purely economic terms, it is one way of considering profits in relation to invested investments. The ROI can also be plugged into the SD model to better inform the impact of the various modes of training along with research results produced by other investigators from the Consortium of Simulation vs. Live Animal Training.

2. KEYWORDS

Simulation training
Procedural training
Live Patient Model
Live tissue training
Stress Inoculation
Combat medic readiness
Combat casualty care
Military preparedness
System Dynamics Modeling
Return on Investment

3. ACCOMPLISHMENTS

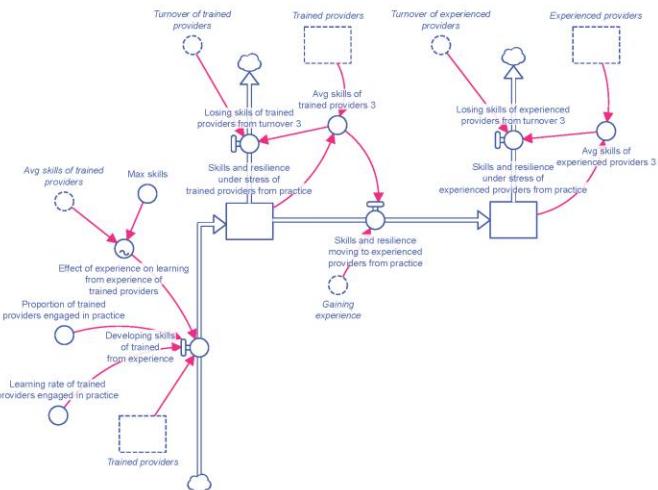
Major Goals of Project:

- a. **Formative Evaluation:** The goal of the formative evaluation was to provide "useful feedback" to the project team conducting other activities: The DoD, trainers, trainees, and the research consortium at large. Depending on the training site and the type of training being addressed, the process involved these stages: the formulation of the issues with live animal and simulation training; the broad conceptualization of the major alternatives that might be considered; the detailing of these alternatives and their potential

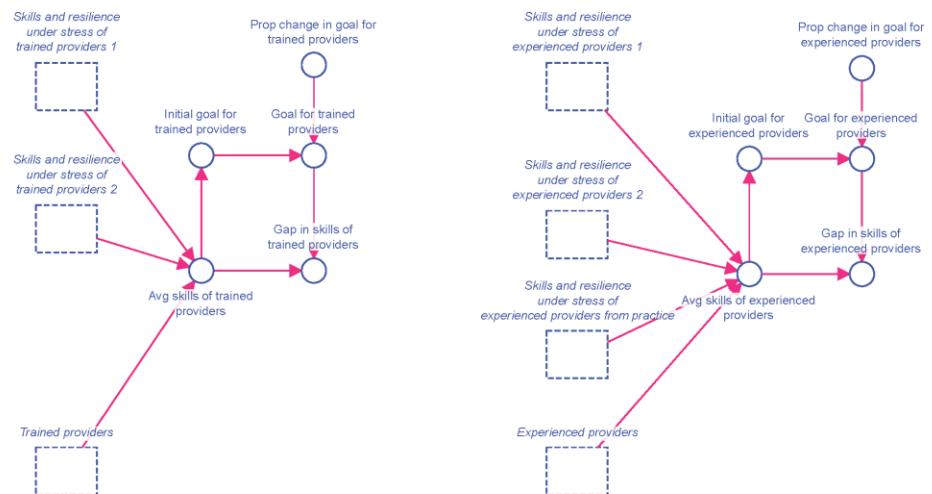
implications; a review of the alternatives. As this project is only partially empirical, we did not make recommendations on alternative or better training models but rather developed a proof of concept that attempted to answer these questions. The formative research addressed several major questions:

- 1) *What is the definition and scope of the problem or issue?* Formulating and conceptualizing methods included brainstorming, focus groups, interviews, nominal group techniques, stakeholder analysis, and concept mapping. While it is understood that the DoD would like to reduce the use of live animals when possible in medical training, a full understanding and a more formal definition of this problem is needed.
- 2) *Where is the problem and how big or serious is it?* The most common method used here is a "needs assessment," which includes a review of existing data sources, interviews of constituent populations including researchers, program directors, trainers and trainees, and focus groups.
- 3) *How should the training program be delivered to address the problem?* Some of the methods already listed apply here and we will also use flow charts to answer this question. Drs. Evans and Post directly observed the training at a variety of sites and had unstructured conversations with a variety of stakeholders. We observed training within their context for a broader understanding of the issues. We observed sampled trainings and people rather than becoming immersed in the entire context. The unstructured conversations occurred with the PI consortium, a sampling of trainers and trainees and finally with subject matter experts in simulation and the medical procedures being taught. In summary, much of this information is understood by the DoD and the Consortium, however, in order for the project team to develop a robust proof of concept for the system dynamics modeling and the return on investment, it was necessary for us to conduct a small independent formative evaluation to inform the rest of this project.

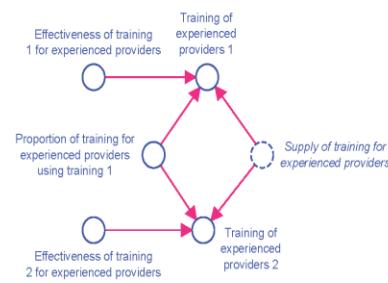
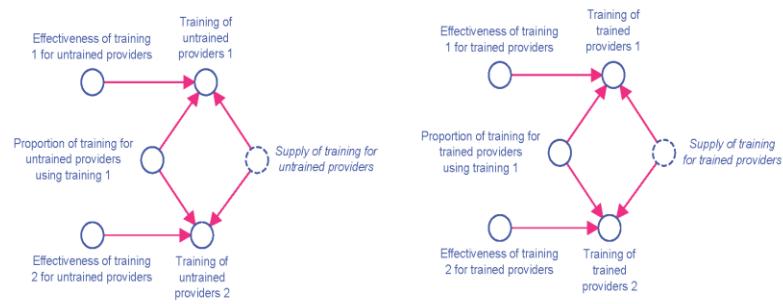
Proof of Concept System Dynamics Model: System dynamics is a way to understand systems and how they change with a specific focus on identifying and evaluating the impact of feedback loops, accumulations (stocks and flows), and the short term and long term consequences of different decisions (Aström & Murray, 2010; Forrester & Senge, 1978; Richardson, 2011). In system dynamics, this is done by building and analyzing informal causal maps and formal computer models of a system that can be simulated. Unique to system dynamics is the potential to involve diverse stakeholders, key informants, and other experts in the process of building and analyzing the results of the model using participatory methods such as group model building (GMB). GMB walks participants through all stages of building a system dynamics model using a series of structured small group exercises, from conceptualizing the problem and elements of the system through formulation, analysis, and implementation of the results. For this project, the primary aim was to develop a "proof of concept" system dynamics model of the implementation of stress simulations for increasing resiliency using group model building. The goal was to illustrate both how this approach can be used and evaluate its feasibility and utility for informing military policies on the use of stress simulations (e.g., What should be the frequency of trainings based on trauma simulations given the decay of resiliency over time? How would differences in the backgrounds of soldiers affect the overall resiliency of the military personnel?). The specific steps for this phase of the study were: Recruit and convene a core modeling team including members of the research team and "gate keepers" for the military to design the group model building (GMB) workshops Vennix & Vennix, 1996). The main deliverables are a system dynamics' seed models for introducing system dynamics, analysis of the model and assessment of the feasibility and utility of this approach as shown below as stock and flow diagrams.



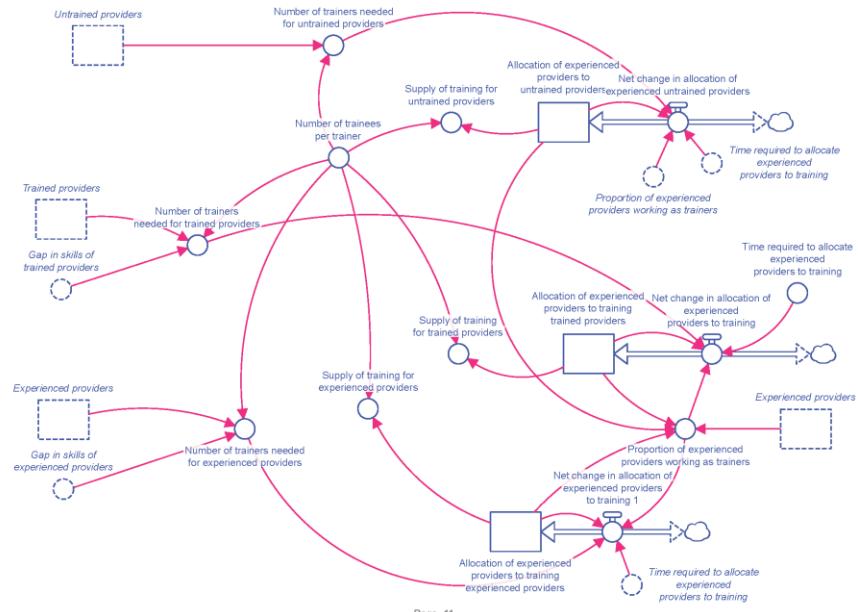
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b. **Assessment of Environmental Stressors-** Environmental stressors are known to impact performance. Dr. Stephen Barnes' Grant W81XWH-11-2-0155#11322004 sponsored by the Department of Defense Telemedicine and Advanced Research Center (TATRC) used sweat measurement as a potential indicator of a stressful response to the combat training environment. This was accomplished by measuring electrodermal activity during didactic and hands-on training. Training participants completed a survey regarding perceived value of the training. A goal of the current study was to incorporate these survey results and interviews conducted at the Combat Casualty Training Consortium meeting at University of Central Florida's Institute for Simulation and Training into the system dynamics concept model for further direct comparison of environmental stressors on live tissue training and simulation-based training for combat casualty care. Other potential measures of "being environmentally stressed" was the use of cortisol levels, blood pressure, temperature, etc.

c. **Preliminary Return on Investment Overview:** Dr. Ted Miller, a health economist developed a thorough analysis plan for a return on investment (ROI) analysis associated with simulation training versus live-animal training. The analysis plan described four major steps to be undertaken in a ROI study in the context of System Dynamics: (1) describe each training alternative; (2) determine staff hours, supplies, travel, and other costs associated with each training approach; (3) calculate costs and ROI, and (4) communicate and document findings. Dr. Miller prepared the first step by undertaking a study of System Dynamics modeling. He then read and interviewed clinicians to fully understand the two training approaches and how their costs can be modeled within a System Dynamics framework.

The second step documented the actual costs associated with each approach. Both types have associated staff time for trainers and for trainees. Live-tissue training has an additional cost for procuring, housing, and disposing of animals used in training. Simulation training carries a cost for the simulation units. If the simulation training is given by contractors offsite, then their costs must be obtained or estimated. We expect that many gaps will remain, and so Dr. Miller also studied the clinical and cost datasets that could provide necessary information. Inputs of machinery, travel, and staff hours came from discussions with experienced trainers, for example, while costs were extracted from DoD databases or from procurement records. The cost of staff and student time was based on the typical distribution of job types they represent (e.g., physician, physician assistant / nurse practitioner, registered nurse, medic) and average labor costs for those job types. Dr. Miller developed used interviews with the PIs to answer questions that cannot be addressed with administrative data. The third ROI step was to pull together results from the first two steps to calculate the costs of each training approach and the ROI. During the initial proof-of-concept study, Dr. Smith and his team will develop a clear, detailed Analysis Plan for calculating each of these components. Dr. Miller also made methodological decisions such as selecting a method for adjusting costs for inflation, determining the discount rate for future costs and benefits, and choosing the perspective of the analysis. Dr. Miller will use the initial proof-of-concept study to develop a presentation plan. He will confer with DoD officials and Consortium researchers to determine the tables and graphics that will provide the most value when presenting ROI results. See COI below.

Accomplishments Under Goals:

a. Formative Evaluation

Drs. Evans and Post attended the Missouri consortium of researchers addressing our hypothesis about whether or not it is possible to safely reduce the use of live tissue while increasing the use of simulators and to have similar outcomes in terms of skills, skill

decay and skill retention. They were present when all the research results were discussed and there was also a phase of the visit whereby Dr. Evans described her role in simulations and to determine if the team of experts felt live tissue could be reduced safely. This resulted in a detailed discussion of the pros and cons of using each. Copious notes were collected by PIs Evans and Post describing the studies and research questions under review.

The Combat Casualty Training Consortium – Dr Stephen Barnes, Principal Investigator, University of Missouri February 18-19, 2014. PIs Evans and Post presented an Introduction to System Dynamics Modeling with an SD model example of decision making in faculty tenure related to female gender, the use of checklists and 'training to competency' in procedural simulation and a discussion on health economics. The objective was to develop a conceptual model that can be used by the Consortium to support conclusions and recommendations to the DoD. Boundaries included: 'live tissue vs simulation,' 'stress inoculation,' 'self efficacy,' 'skills transfer to the clinical setting of combat,' and 'skills decay over time.'

On the topic of live tissue vs. simulation, the discussion focused on exploring the following questions:

- What are the advantages of simulation training?
- What are advantages of a live tissue model?
- Are advantages and disadvantages specific to individual procedures?
- For animal models:
 - How were species selected for each procedure? Were there issues related to anatomic accuracy of the animal model compared to humans?
- For task trainers:
 - Did the trainers fail? Was the fidelity of the partial task trainers adequate?
- Since testing occurred on a simulator, is it possible the results were influenced by the simulation trained group being more comfortable with a simulator? How was this addressed?

With regard to stress inoculation, the discussion focused on:

- How was electro-dermal activity chosen as the measurement of stress?
- Were other physiologic measurements considered?
- Did you evaluate for a maximum level of stress that might be detrimental to retention?

When working with groups unfamiliar with SD modeling, modelers need a quick way to introduce the iconography of the approach and some of its framing assumptions, which are often called concept models. The concept model represents our approach to early view of the problem in its systemic context. (See Appendix 1)

In this concept model, "Combat Medics" is the fundamental stock and the "Total Medic Skill" is the underlying attribute. Note that "Total Medic Skill" is a net function of "Skill Increase by Experience", "Skill Increase by Appointment", "Skill Increase by Training", and "Skill Loss in Turnover" (i.e., medic attrition).

b. Proof of Concept System Dynamics Model: Achieving desired levels of combat casualty care skills and resiliency under combat stress using different training modalities (e.g., live tissue training, simulated medical procedures) is a dynamic resource allocation problem. Essential features of this problem are 1) training modalities vary in their effectiveness and rate of skill decay by the type of skill, 2) experienced providers are a critical resource for delivering training, and 3) training is required to maintain existing skills for trained and experienced providers. This contributes to a set of variables affecting each other through one or more feedback mechanisms that pose a set of

complex tradeoffs about how to best allocate scarce resources to maximize the quality of care.

To address this dynamic resource allocation problem, we developed a prototype system dynamics computer simulation model. System dynamics is a method for understanding the behavior of complex systems using informal maps and formal models with computer simulations from a feedback perspective (1). As such, system dynamics (SD) provides a novel way to gain insight into systems and formulate better policies. The purpose of the combat casualty care system dynamics prototype was to provide a “proof of concept” for how system dynamics computer modeling and simulation might be used to inform decisions about how to develop and allocate a variety of training modalities to maximize quality of emergency medical care in combat settings.

To inform the modeling process, we developed a preliminary model, conducted group model building workshops, and drew on key informant interviews with experts familiar with combat medicine training. Group model building (GMB) is a participatory methods for involving experts and stakeholders in the process of conceptualizing and building a system dynamics models (e.g., 2, 3). We conducted two 90-minute GMB workshops, one with emergency medicine providers with combat experience and a second session of providers without combat experience. The results of the resulting diagrams were synthesized, and then reviewed as part of a key informant process led by the larger research team.

The initial prototype was developed using Vensim PLE, but eventually rebuilt and revised using Stella Architect 1.1, which supports the development on online web interfaces for experimenting with the simulation model.

Figure 1 provides a high level overview of the final prototype Combat Casualty Care Model version 4.0.1 depicting some of the major feedback loops and the basic “aging chain” for providers (the variables in boxes including untrained providers, trained providers, and experienced providers). The double lines with the circular valves represent rates of change (e.g., recruiting, training, gaining experience) and the clouds represent the sources and sinks that define the material and information boundaries of the system. The single lines with arrow heads represent causal links where the polarity of the sign represents the direction of association. So, for example, the *greater* the gap in skills for trained providers, the *more* trainers are needed indicating a positive link. Similarly, the *higher* the proportion of experienced providers allocated to training, the *slower* the net change in allocation since there are fewer experienced providers left to allocate to training indicating a negative relationship.

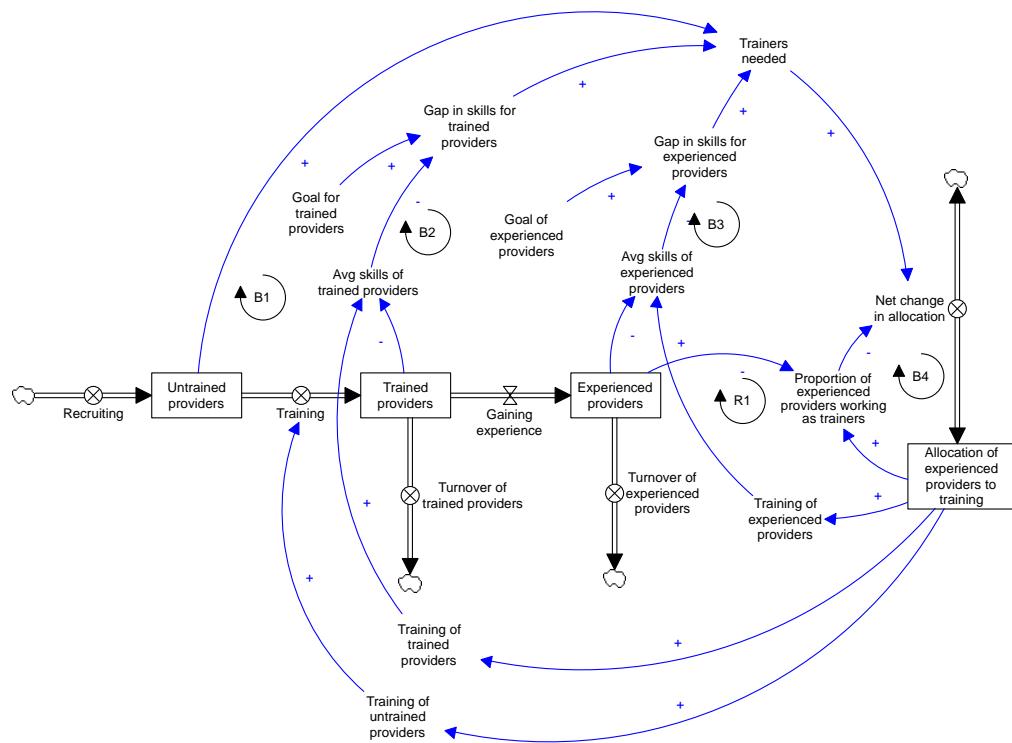


Figure 1 Conceptual overview of Combat Casualty Care system dynamics model

The actual model disaggregates skills and resiliency under stress by the training modality (training 1 and training 2), practice experience, and experience level of the providers (untrained, trained, and experienced). Skill and resiliency developed through training are considered vulnerable to skills decay, while skill and resiliency developed through practice experience are considered more robust and permanent. The final model has 14 stocks or state variables, 133 initialization equations, and 87 runtime equations.

The user sets the characteristics of training 1 and training 2 including the effectiveness of each training for developing skills and resiliency under stress (a 100-point scale from 0=no skills and resiliency to 100=maximum skills and resiliency) for each level of training (untrained, trained, and experienced), rate of skill decay, and cost in addition to the proportion receiving training 1, and hence also the proportion receiving training 2 (1-proportion receiving training 1). This allows the user to consider a wide variety of situations. Importantly, the comparisons are *only with respect to one kind of medical procedure*. This model does not represent all the complex interactions that can occur when performing one medical procedure is contingent on competencies related to another medical procedure (this is something that could, however, be captured in a much more sophisticated research model).

We have developed a simple, demonstration web-interface for the model to illustrate the possibilities. This provides a brief introduction to the model and interface, takes the user through a parameter setting page for the two training modalities, and then lets the user conduct a series of experiments to test various implications of allocating training, setting goals for maintaining skills and resiliency for trained and experienced providers, and addressing turnover. Note that the model starts initially in a dynamic equilibrium that is calculated internally based on user supplied values. To see a dynamic pattern as shown in Figure 2, one must first set a goal to increase (or decrease) the desired level of change for trained providers and/or experienced providers.

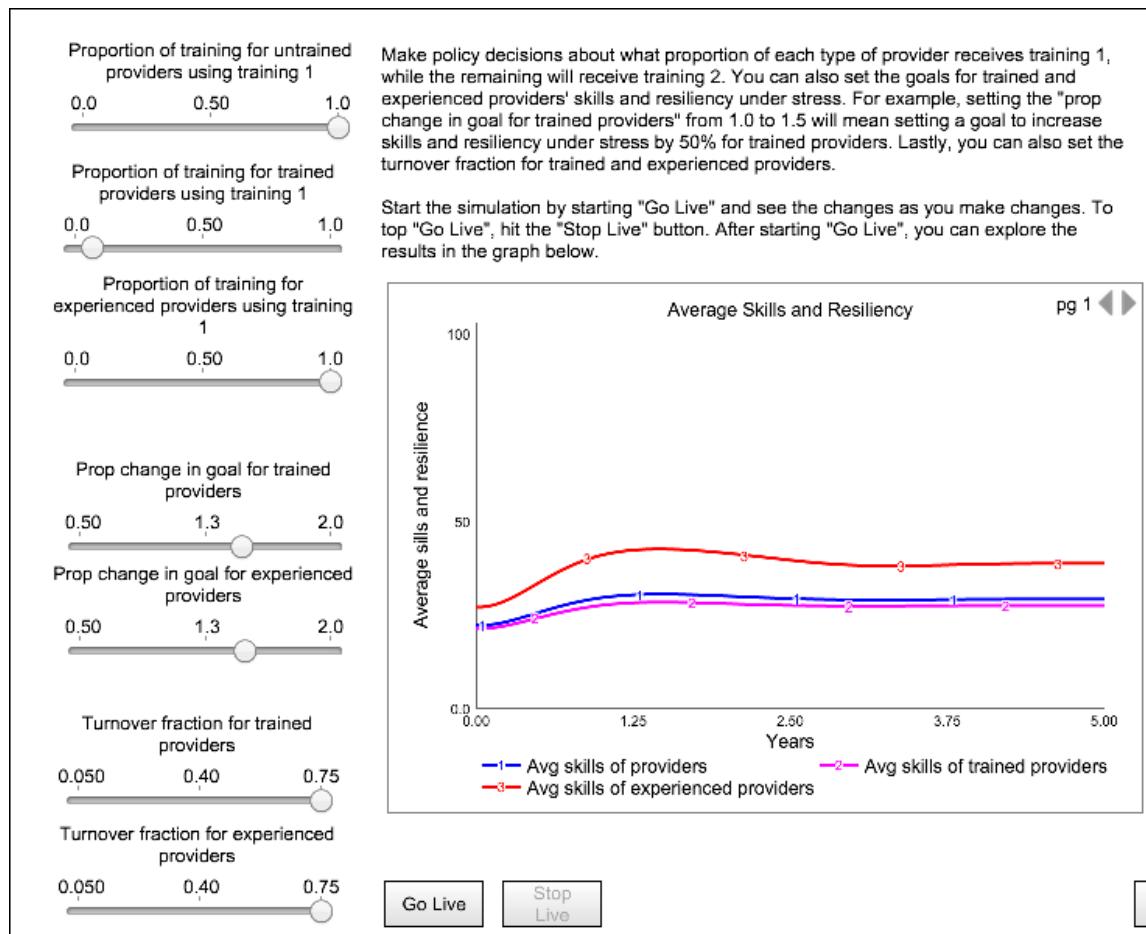


Figure 2 Example of a page from the web-interface

Summary

The Combat Casualty Care model demonstrates the basic feasibility of creating a system dynamics simulation model to address the question about how to best allocate training resources to maintain quality of emergency medicine care. The process of developing the model also generated a number of insights into the system and some of the underlying complexities discussed during GMB workshops and key informant interviews, particularly with the medical providers with combat experience.

For example, a recurring theme during the discussions when forced to describe the dynamics around specific skills and resiliency with respect to training modalities. Live tissue training, for example, varied in its effectiveness by the type of procedure, and there could be interactions between competencies for one procedure another procedure.

Future efforts should consider arraying the skills and resilience under stress by a detailed list of procedures and the potential interactions in a matrix. Although existing data may not be sufficient to fully specify all the parameters, working with expert key informants would likely be able to establish reasonable estimates.

A second insight and point for potential research might focus on understanding more precisely the relationship between experience and dynamics of skill decay. For example, to what extent does acquiring a skill using one training technique help retain skills learned through other training technique. In the GMB workshops, a frequent comment was the effect that exposure to blood under stress could help inoculate providers to stress (something that was generalizable to any experience involving exposure to blood and

perhaps others). Similarly, questions arose during the modeling process about the rate of skill decay by experience level. Do trained providers with little experience have greater skill decay for a specific procedure than experienced provider? The answers to these kinds of questions turned out to have important implications for the dynamics of average skill and resiliency and would require further study for a more fully developed system dynamics model.

Lastly, many aspects of this structure may have much more generalizability to other areas where training is often done by experienced providers, skills decay, performance depends on successfully completing one more procedures, and performance is affected by stress (e.g., other roles in combat).

c. Assessment of Environmental Stressors

For purposes of this study, study subject “sweating” was used to measure the environmental stressors.

d. Preliminary Return on Investment: Traditionally, training for invasive procedures included either the apprenticeship model in which the trainee learns technical skills under the guidance of an expert or the use of live tissue patients (LTPs) to allow the trainee to gain these critical skills. Dr Roy Ziegelstein of Johns Hopkins University believes live tissue patients give students “the experience of being directly responsible for decisions in life-threatening situations” (Fears 2016). However, over the past twenty years, the development of high fidelity mannequin simulators and procedural task trainers offers an alternative method of training medics for the combat field. It has been postulated that live tissue maximizes the realism, stress and emotional connect present in actual medical emergencies in the combat setting. Despite that benefit, improved simulation technology and concerns about animal rights have led all US medical schools to minimize surgical training on living tissue (Fears 2016). The military, however, has continued to use live tissue models to prepare personnel to render medical assistance on the battleground. We compared the costs of combat casualty training using living tissue versus simulators. Simulators included high fidelity mannequin simulators, procedural task trainers and hybrid simulators (human volunteer strapped to a half-body mannequin).

METHODS We conducted the analysis from the US military’s perspective. We organized the methods around 4 questions:

1. What alternatives will be assessed?
2. What are the costs of each alternative?
3. How do the benefits differ between the alternatives?
4. How sensitive are the findings to assumptions and uncertainty?

Alternatives Assessed

1. Living Tissue: one session of combat casualty training on goat tissue.
2. Mannequin Only: one session of simulator training without a volunteer patient
3. Hybrid: one session of simulator training with a human providing half of the patient’s body) with wounds on lower portion of body (simulator).
4. Ride Along Supplement: one day of trainee ride-along as a paramedic’s shadow, with the Emergency Medical Service (EMS) agency paid a \$100 ride-along fee.

Provided each alternative training approach teaches the same medical procedures, session length will not vary between alternatives 1-3.

Costs. Costs for live tissue were obtained from interviews with military program managers. Simulator costs were provided from GSA schedule. Hybrid surgical simulations used non-commissioned officers or wounded warriors who volunteered to participate. We estimated a typical simulation requires 3 hours of the volunteer’s time. In June, 2016, median annual non-commissioned Army officer salaries were \$26,510 for E4 and \$28,516 for E5 (www1.salary.com) for a 2,000-hour work-year. We used the \$27,513 average of these medians. We added noncash compensation including health care,

retirement pay, child care and free or subsidized food, housing and education. Those supplements represent roughly 60 percent of total compensation (<http://www.goarmy.com/benefits/total-compensation.html>), hourly compensation averages \$34 ((27,513/2000)/(1-0.6)).

We stated all monetary estimates in 2016 dollars. We used the 2.9% discount rate mandated by the US Office of Management and Budget (2016) and US Department of Defense (2015) to amortize future costs.

Benefits. All options will yield the necessary medical skills. Live tissue patient training conceivably could prevent a new medical provider from freezing the first time (s)he provides treatment during active combat. A ride along supplement seems likely to have a similar effect, and hybrid training may as well. The effect with hybrid training may be somewhat attenuated.

Sensitivity Analysis. We examined how the costs varied when we changed alternate assumptions and priced three competing simulators.

RESULTS

As Table 1 shows, a typical live tissue training session requires an estimated \$675 in disposables per trainee, with most of the cost for live model acquisition and disposal. Because all hands-on training alternatives last equally long and require one trainer per trainee, neither trainee nor trainer time/costs will differ among the alternatives, so we did not cost them.

Table 1. Cost per Live Patient Model Session

Cost Category	Cost per Trainee
Live Model Purchase (Goat)	\$275
Transfer/Storage Cost*	50
Anesthetization Cost	125
Disposal Cost	225
TOTAL	\$675

* Assumes at least 4 medical personnel are trained on the same day.

Table 2 shows that manikin-only simulations cost an estimated \$452 per trainee, only slightly less than \$472 cost of a hybrid simulation assisted by a human. Both cost substantially less per trainee than live tissue training. In sensitivity analysis, if the full manikin was used in hybrid training, hybrid training costs would rise to \$554. If the manikin plus warranty had a 7-year useful life rather than 10 years, costs per trainee would rise to \$507 for the full manikin and \$497 for hybrid training. Undiscounted the costs are \$433 for the full manikin and \$463 for the hybrid. Using a 3% discount rate would raise each manikin option's cost by \$1.

DISCUSSION

This analysis has limitations. It counted neither any gain in emotional readiness from live tissue training nor harm to the military's reputation and possible disruption of training efforts associated with use of live tissue. Manikin costs were drawn from GSA schedule. They are based on the three mannequins usually purchased for the training analyzed but may not reflect the exact options selected in mannequin purchase. The estimated useful mannequin life also is an approximation.

Despite these limitations, it is clear that simulated training costs less than live tissue training. Hybrid training increases realism and emotional preparation at a relatively modest cost, especially if it permits use of a half manikin rather than a full-body mannequin.

Table 2. Cost per Mannequin Session

Item	Price Range	Per Trainee
MANNEQUIN ONLY		
Full-body mannequin (one trainee/week, 10 year life)	\$65,000-\$80,000	\$164
Warranty (per trainee cost adjusted for year 1 free)	\$7,350/year	132
Blood	\$6.40/gallon	6
Skin for needle chest decompression, and surgical cricothyrotomy	\$90/set	90
Lubricant	\$10/tube	10
Partially reusable moulage (assume 10-15 uses)	\$525-\$750	50
TOTAL – full manikin		\$452
HYBRID HALF-BODY MANIKIN + HUMAN		
Half-body manikin (one trainee/week, 10 year life)	\$32,500-\$40,000	\$82
Manikin supplies & warranty as above		288
3 hours volunteer time (E4/E5 median salary + supplements)	\$34/hour	102
TOTAL – half manikin		\$472

Source: GSA Schedule

Opportunities for Training and Professional Development Provided by Project

The Yale Team had the opportunity to visit some DoD medical training sights as well as to see how the simulation section in Tampa, Florida was used to train military personnel for combat.

Dissemination of Information to Communities of Interest

This study in its entirety will be shared with the DoD in general, TATRIC, the two live tissue consortiums, simulation researchers, and system dynamics experts.

Next Reporting Period:

Nothing to Report. This is the final report

4. IMPACT

Impact on the the development of principal disciplines of the project

This study was conducted as a proof of concept for Dr. Terry Rasch on how system dynamics could be employed to assess the impact and nuances of funded DoD research. Every year, the biomedical division of the DoD spends in excess of a billion dollars per year on research. It is not known if these funded studies are having impact on soldiers or pushing the medical body of knowledge in general forward. As system dynamics modeling allows us to look at recursive relationships, to mix qualitative and quantitative data together, to simulate out results with changes in practice or policy, it is a superior method to assess impact and return on investment for the DoD's portfolios of research.

Impact on other disciplines

The results of this study will be presented to the DoD, TATRIC, and Simulation researchers in general. This methodology can be used in other disciplines as this study suggested. In general,

most research and opinions of DoD physicians did not believe that live tissue could be reduced, however, when comparing live tissue training to simulators, there was not much difference. This study demonstrates a mechanism to disaggregate perceptions from facts and also how to use the most impactful combination.

Impact on technology transfer

Given that this study resulted in a simulation program that allows the user to modify study parameters and to test out policies of live tissue research, the system itself can help those experiment with various combinations to find optimal outcomes. Furthermore, this live system located on the web, will be disseminated for use by non DoD and DoD medical researchers.

Impact on society beyond science and technology

Using live animals for medical training has some adverse outcomes for the DoD. Specifically, persons from PETA and other animal rights activists are calling for the DoD to end training that involves animals. This study allows us to safely reduce training on animals and should address political issues with persons who feel animal research is unethical.

5. CHANGES/PROBLEMS

Changes in approach and reasons for change

The largest challenge we experienced was we expected that since we were conducting DoD research that we would have access to military bases to observe training of medical personnel. It was not until we involved a former retired military person to contact the correct people, we could not access the bases. After accessing, the study went well. The initial goal of the project was to directly observe both simulation training and live tissue training at military sites. The primary site for observation of live tissue training was the Joint Special Operations Medical Training Facility at Fort Bragg MSTC in North Carolina.

Actual problems or delays and actions to resolve them

Since accessing the military sites and DoD medical training took longer, our research team had to apply for a No cost extensions (NCE). The DoD willingly gave us the extension and we were able to accomplish our project goals and objectives.

Final NCE through 9 July 2016 (Appendix) – Delivery Schedule change from 10-Sept-2014 to 09-Mar-2016 to 10-Sept-2014 to 09-Jul-2016

Changes that had a significant impact on expenditures

There were no significant impact on expenditures.

6. PRODUCTS

System Dynamics Model: The following link connects the end user to the live system dynamic's model. <https://sims.iseesystems.com/psh/emt/#page1>

Return on Investment:

The aforementioned live system dynamic's model also includes the return on investment. There are several pages that are accessible by the arrow in the bottom right corner. On the final page, the end-user must click on the upper right tab to reach the final outcomes and allows the end-user to experiment with the model by changing parameters to see what types of results in terms of training will occur under varying conditions including return on investment.

7. PARTICIPANTS AND OTHER COLLABORATING ORGANIZATIONS

Individuals who have worked on the project:

PIs: Leigh Evans and Lori Post were responsible for the study outcomes and products. Ms. Christal Esposito served as a project manager. Ms. Joanne McGovern served as a site consultant. Dr. Peter Hovmand conducted the Group Model Building exercises. We relied on two groups. The first was military physicians and the second was simulation only physician trainers.,

Group Model Building Sessions (May 2015)

Military background:

- a. Dr. David Hile – Yale University
- b. Dr. Cynthia Brandt – Yale University
- c. Dr. David Della-Giustina – Yale University
- d. Dr. Paul Porter – Brown University
- e. Dr. Craig Goolsby – USUHS
- f. Dr. Joseph Schmit – Baystate Hospital/Tufts University

Simulation expert background – No military training

- a. Dr. Leigh Evans – Executive Director, Yale Center for Medical Simulation
- b. Dr. Jay Bonz – Director of Procedural Simulation, Yale Center for Medical Simulation
- c. Dr. Kelly Dodge – Director of Resident Simulation, Yale Center for Medical Simulation
- d. Dr. Tiffany Moadel – Medical Simulation Fellow, Yale Center for Medical Simulation
- e. Dr. Kimberly Davis – Chief, Trauma, Critical Care and Emergency General Surgery, Department of Surgery, Yale School of Medicine
- f. Dr. Scott Dale – Emergency Medicine Resident, Yale-New Haven Hospital
- g. Dr. Susan Varga – Emergency Medicine Resident, Yale-New Haven Hospital

Change in active support of PD/PI(s) or senior/key personnel:

Other organizations:

At the writing of the first proposal to the DoD, we were under the assumption that we had to use an IDIQ funding mechanism. To that end, we connected with a health economist from Truven Health. After beginning the project, we felt that his skills were not sufficient to conduct a return on investment. Since we used a BAA mechanism and were free to use another health economist, we switched from Truven Health to Pacific Institute for Research and Evaluation. Dr. Ted Miller did the final return on investment.

8. SPECIAL REPORTING REQUIREMENTS

Quad charts:

We were required to present initial findings to the DoD last June 2015, we also filed monthly status reports and finally, two quad charts. Here is our final quad chart.

Evaluation of the Effectiveness of Live Tissue Training versus Simulation Training and Stress Inoculation

Log #14154002
W81XWH-14-C-1392



PI: Leigh Evans, MD, Lori Post, PhD

Org: Yale University / Emergency Medicine

Award Amount: 417,751

Study/Product Aims					
The assessment benefits the Department of Defense by:					
1. Establishing a system dynamics proof of concept before engaging in a full study to determine if simulation can replace live animal training in some procedures.					
2. Establish a Return on Investment proof of concept before conducting a full cost study to determine if specific modes of training have better return on investment.					
Approach					
1. Develop a conceptual systems dynamic model of live tissue vs. simulation training.					
<ul style="list-style-type: none"> Conduct literature review Develop seed model from the literature and transcripts of the Live Tissue Vs. Simulation Training Consortium Meeting in Tampa FL Recruit and convene civilian and military physicians to review the system dynamics Develop the systems dynamic model 					
2. Conducting a formative evaluation – Define the scope of the problem, identify possible solutions, determine if there are any barriers which would prohibit the implementation of the solution.					
3. Determining the return on investment (ROI) – Describe each training alternative, determine costs affiliated with each approach, calculate costs and ROI.					
Timeline and Cost					
Activities	CY 2015 Sept-Nov	CY 15-16 Dec-Feb	CY 2016 Mar-May	CY 2016 June-Aug	CY 2016 Sept-Nov
Develop and test a conceptual systems dynamic's model					
Conduct formative evaluation					
Determining the return on investment (ROI)-					
Estimated Budget	\$36,591	\$166,021	\$66,962	\$34,859	\$56,659

```

graph LR
    A[Document review  
Interviews  
Reports] --> B[Preparing preliminary model  
Seed structure]
    B --> C[Group Model Building Sessions  
Military  
Non-military]
    C --> D[Review by participants (member checking)  
Synthesis  
Combined causal map]
    D --> E[Proof-of-Concept Simulation Model  
Simulation model]
    E --> F[Next steps]
  
```

The flowchart illustrates the research process. It begins with a 'Document review' step, which includes 'Interviews' and 'Reports'. This leads to a 'Preparing preliminary model' step, specifically a 'Seed structure'. This is followed by 'Group Model Building Sessions' involving 'Military' and 'Non-military' participants. The process then moves to 'Review by participants (member checking)' and 'Synthesis', resulting in a 'Combined causal map'. Finally, a 'Proof-of-Concept Simulation Model' is developed, leading to 'Simulation model' and 'Next steps'.

Completed the quantitative analysis of the DoD LTR/Simulation Consortium and literature review. Developed the seed model and convened civilian and military physicians to refine the system dynamic model. Conducted return on investment and system dynamics model

Goals/Milestones

CY 2015 Goal 1 – Initiate the development of a conceptual systems dynamic model of live tissue vs. simulation training.

- Develop seed model from the literature and transcripts of the Live Tissue Vs. Simulation Training Consortium Meeting in Tampa FL
- Recruit and convene civilian and military physicians to review the system's dynamics
- Validate seed model adjust as required

CY 2015 - 16 Goal 2 – Conduct formative evaluation

- Conduct site visit to military MTF to evaluate the model and build upon it
- Define the scope of the issues surrounding live tissue vs. simulation training and compare the advantages/disadvantages of both
- Identify possible solution sets, determine if there are any barriers which would prohibit implementation
- Finalize and run the system dynamic model to determine how many lives will be saved over time utilizing Live Tissue Vs. Simulation Training

CY 2016 -17 Goal – Determining the return on investment (ROI)

- Identify all cost associated with Live Tissue Vs. Simulation Training
- Execute a live system dynamics model combining data and group model building and observation data

Comments/Challenges/Issues/Concerns

A no cost extension for 15 months was given due to delays in the start of the project due to sequestration and access to military base training.

Budget Expenditure to Date

Projected Expenditure: \$417,751

Actual Expenditure: \$417,751

9. APPENDICES

Given that the main product of this study is an on line system dynamic's model of live tissue training vs. simulator training, we do not have an appendix. Rather, we have a link to the website. Furthermore, we are in the process of publishing our findings.

<https://sims.iseesystems.com/psh/emt/#page1>

REFERENCES:

1. Richardson GP. Reflections on the foundations of system dynamics. *System Dynamics Review*. 2011;27(3):219-43.
2. Vennix J. *Group model building*. New York: John Wiley & Sons; 1996.
3. Hovmand PS, Andersen DF, Rouwette E, Richardson GP, Rux K, Calhoun A. Group model building "scripts" as a collaborative tool. *Systems Research and Behavioral Science*. 2012;29:179-93.